YOUR GLOBAL MOBILITY
ENGINEERING EXPERTS

EDAG GROUP

# BATTERYMODEL FOR FULL VEHICLE SIMULATION

EDAG

# OUR
# FACTS & FIGURES

**1969**
**FOUNDATION**

**~ 60**
**LOCATIONS WORLDWIDE**

**19**
**COUNTRIES**

**~ 8,000**
**EMPLOYEES**

**33**
**SHOW CARS**

**2015**
**IPO**

**~ 5 %**
**TRAINING RATE**

**650**
**MILLION REVENUE**

**~ 2-3%**
**CAPITAL EXPENDITURE ON REVENUE**

## EDAG WORLDWIDE

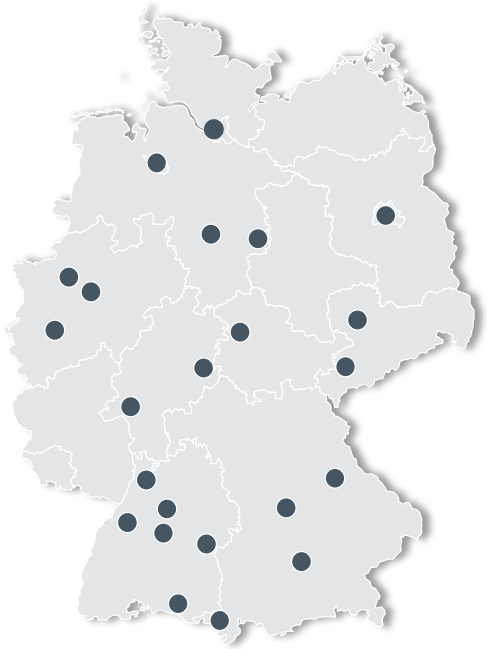
**Europe:**
- Germany
- United Kingdom
- Italy
- Netherlands
- Poland
- Sweden
- Switzerland
- Spain
- Czech Republic
- Turkey
- Hungary

**Asia:**
- China
- India
- Japan
- Malaysia
- Russia

**North & South America**:
- Brazil
- Mexico
- USA

## EDAG GERMANY

- Berlin
- Bremen
- Dortmund
- Eisenach
- Friedrichshafen
- Fulda
- Hamburg
- Hannover
- Ingolstadt
- Karlsruhe
- Köln
- Leipzig
- Lindau
- München
- Neckarsulm
- Recklinghausen
- Regensburg
- Stuttgart
- Ulm
- Weinheim
- Wiesbaden
- Wolfsburg
- Zwickau



# OUR
# RANGE OF SERVICES

**Vehicle Engineering**
- Complete vehicle: Development & Management
- Vehicle Integration
- Body in White
- Chassis
- Interior & Exterior
- Drive Train
- Low-volume Series & Edition

## 360° VEHICLE ENGINEERING

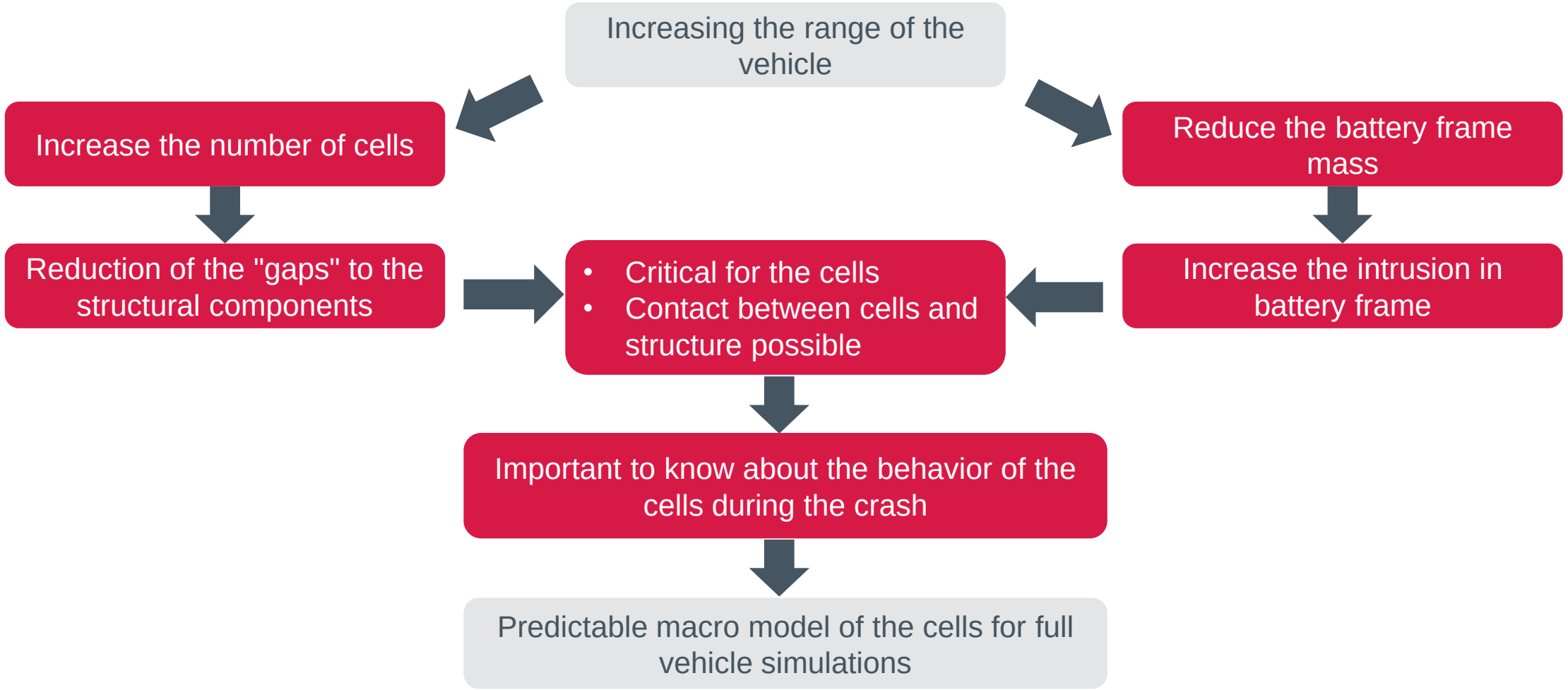
**Software & Digitalisation**
- Mobility Software
- Connected Services
- Smart City
- Smart Factory

**Electrics / Electronics**
- Vehicle Electrics & Electronics
- eDrive & Energy Systems
- Comfort & Body Systems
- Autonomous Drive & Safety
- Connectivity & User Experience

## 360° PRODUCTION ENGINEERING

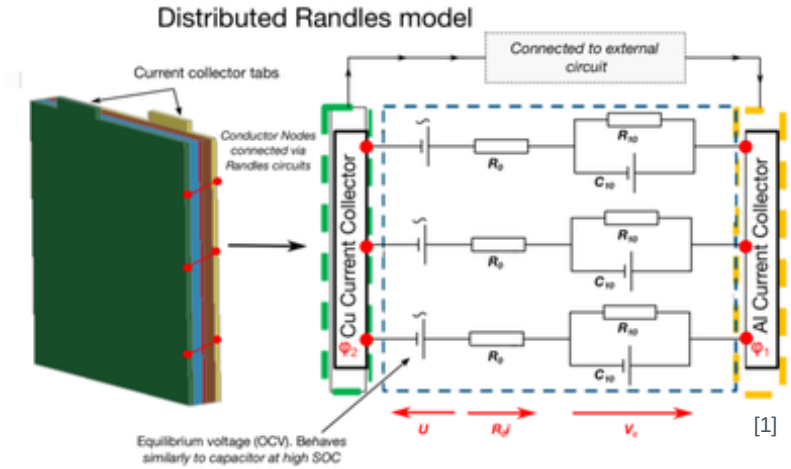
**Production Solutions**
- Feasibility Analysis
- Production Planning
- Systems Engineering
- Fixture Technology
- Plant Automation
- Production Optimisation
- Safety Engineering Services

# BATTERYMODEL FOR FULL VEHICLE SIMULATION
## MOTIVATION



# BATTERYMODEL FOR FULL VEHICLE SIMULATION
## BASIC INFORMATION

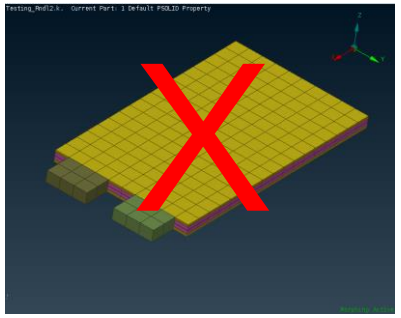
- Coupling of mechanical and electrical solvers
- Use of a Randles Circuit for cell simulation
- Using of LS-Dyna short circuit criteria



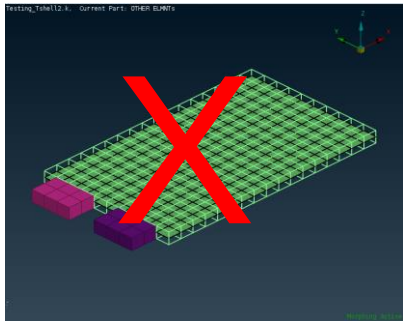
[1]

- Simulation of cylindrical, prismatic and pouch cells possible
- We are using a Randle BatMac model to keep the simulation time in acceptable limits

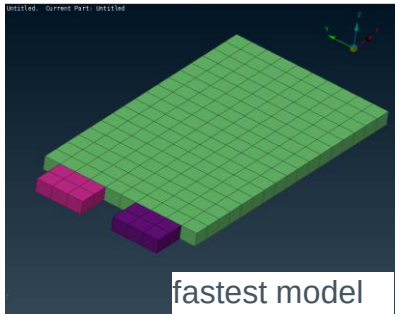
Randles Solid



Randles T-Shell



Randles BatMac



fastest model

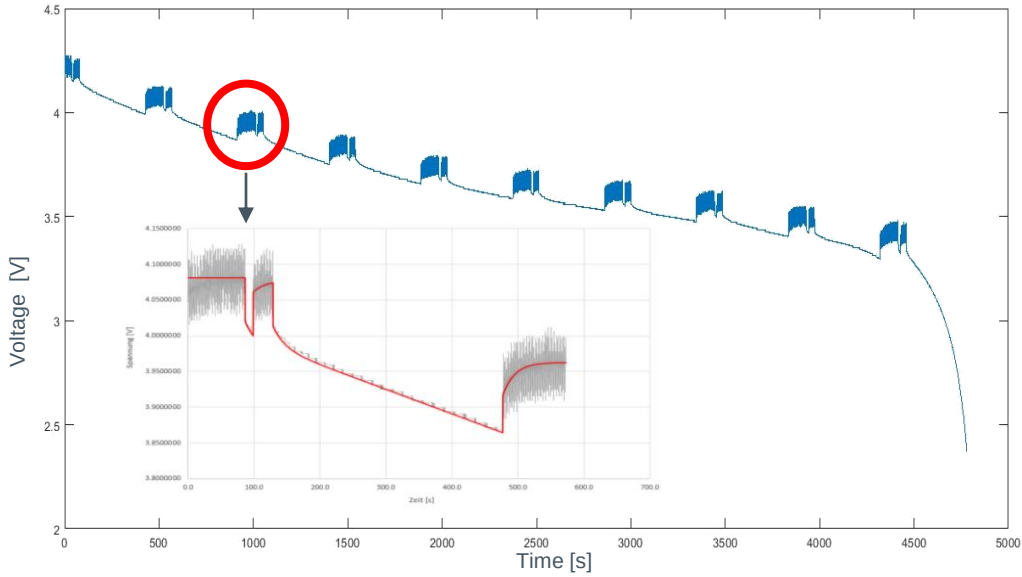
[1] Dyna Examples: https://www.dynaexamples.com/em/battery

# BATTERYMODEL FOR FULL VEHICLE SIMULATION
## ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY

B154 x L248 x H12
44Ah

- Cell model: LC-44 Litacell
- Electrochemical impedance spectroscopy every 10% State of Charge (SoC)
  - Test sequence of discharge cycles (from 100% to 10%) and rest phases
- Determination of the characteristic values for the equivalent circuit diagram
  - Characteristic values were subsequently adjusted using a curve fitting method in Matlab



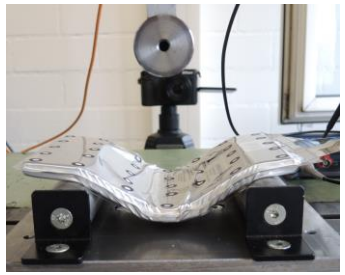



# BATTERYMODEL FOR FULL VEHICLE SIMULATION
## TESTS FOR VALIDATION

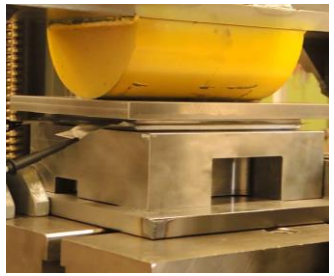
B154 x L248 x H12
44Ah

**Pouch cell**

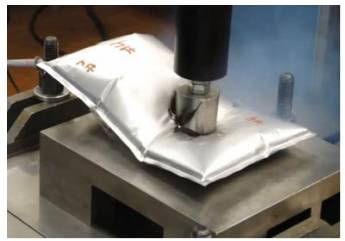
**3 point bending test**



**Flat stamp**



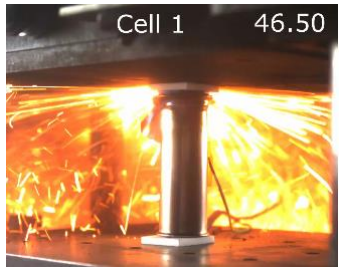
**Sphere**



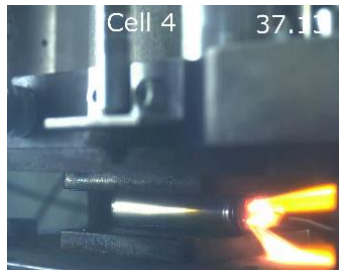

21700
5000mAh

**Cylindrical cell**

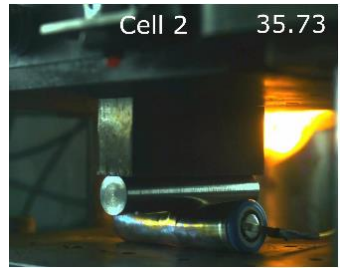
**Axial**




**Radial**

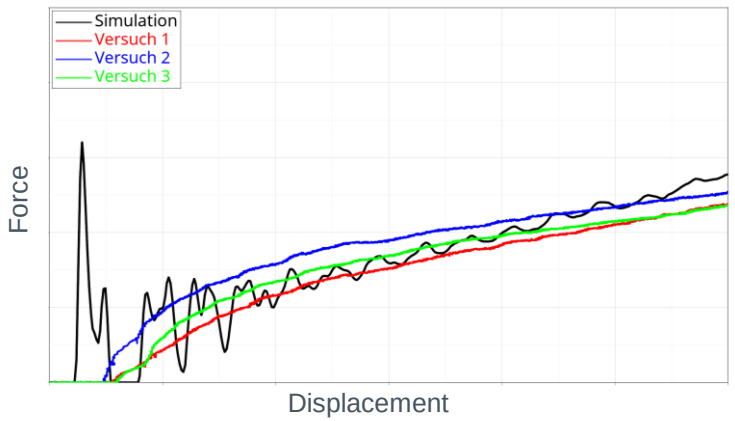


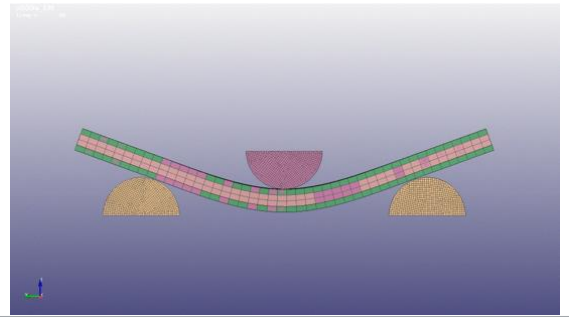

**Round bar**



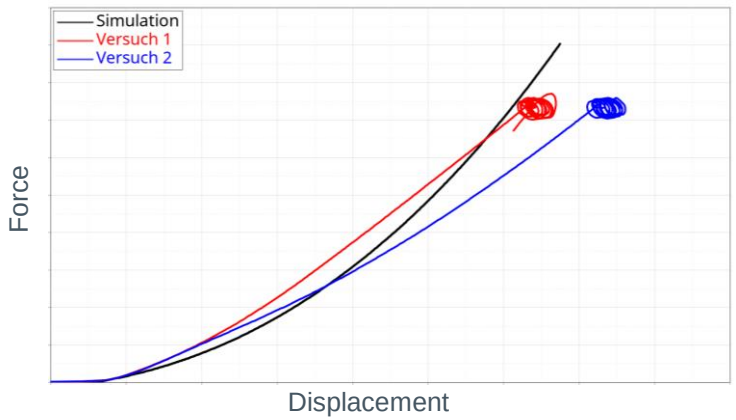
# BATTERYMODEL FOR FULL VEHICLE SIMULATION
## POUCH CELL

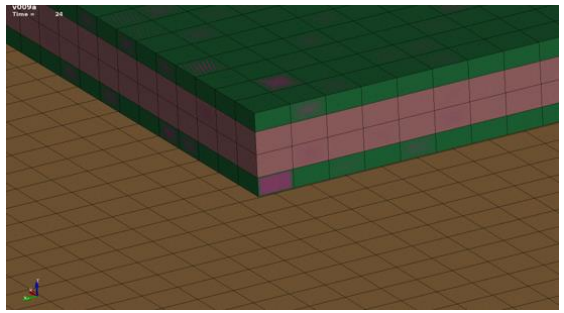
### Bending



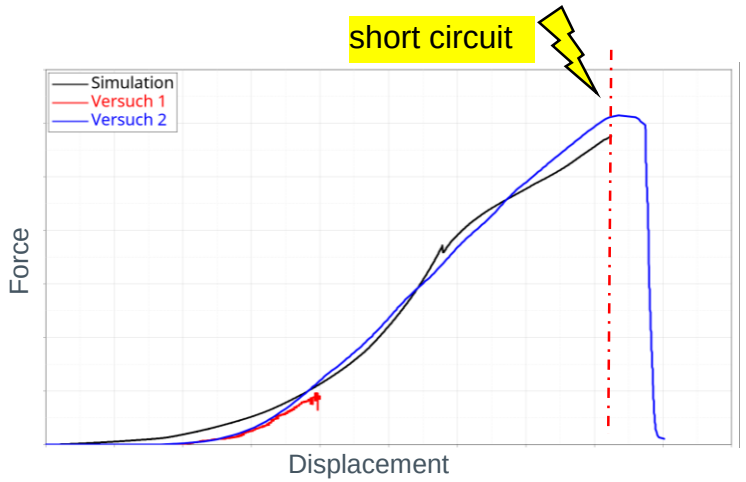



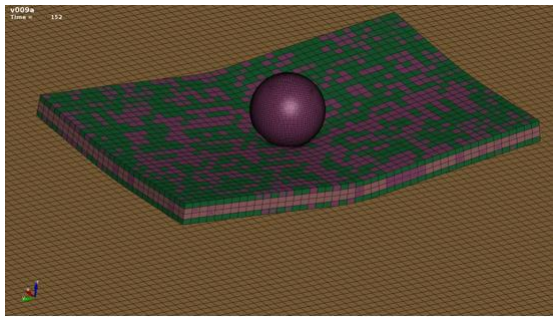
### Flat stamp



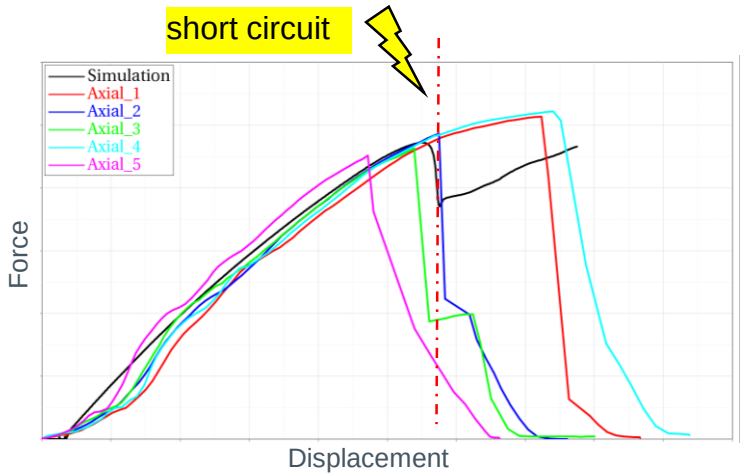
### Sphere

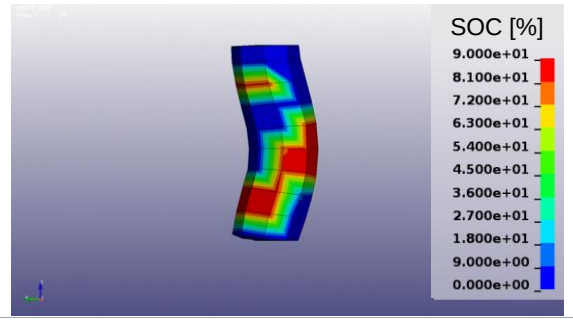


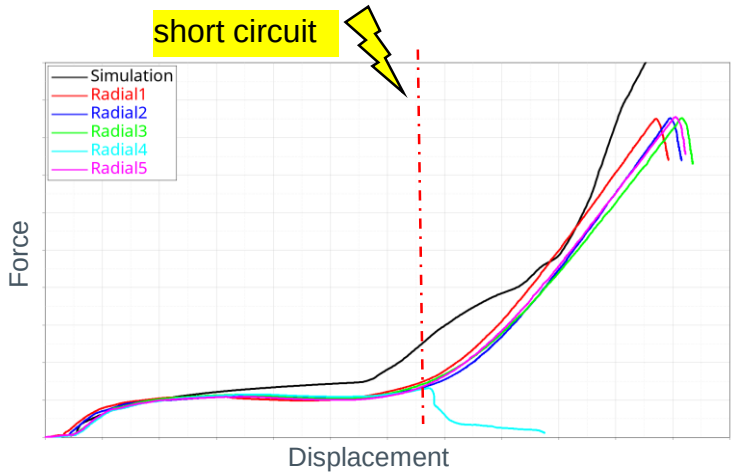
# BATTERYMODEL FOR FULL VEHICLE SIMULATION
## CYLINDRICAL CELL

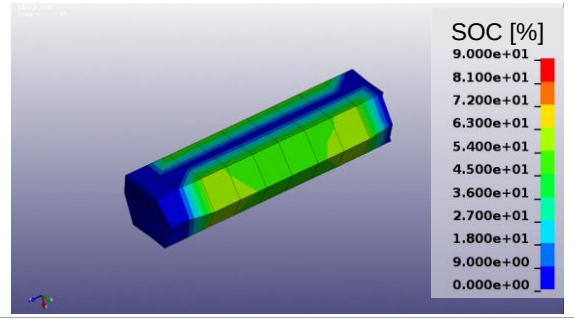
### Axial



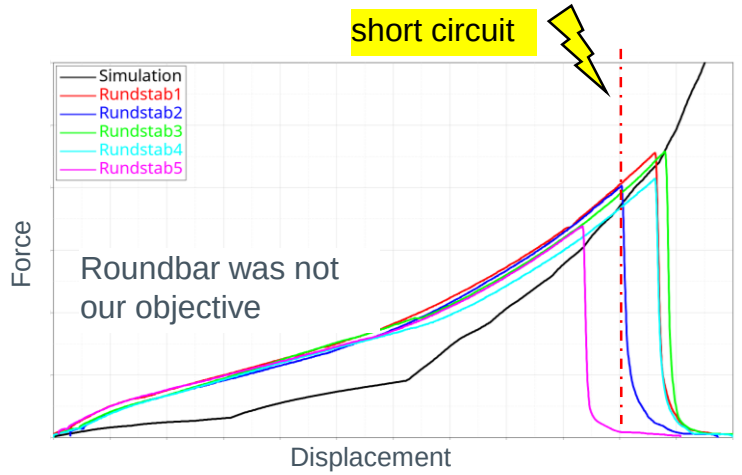



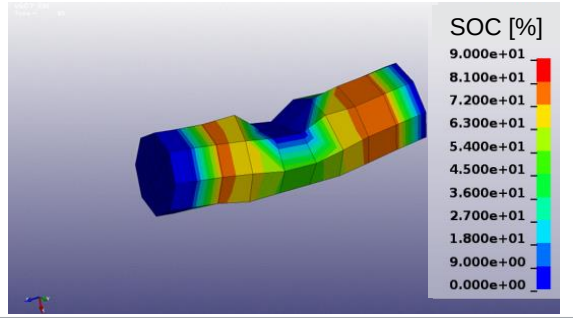

### Radial




### Round bar



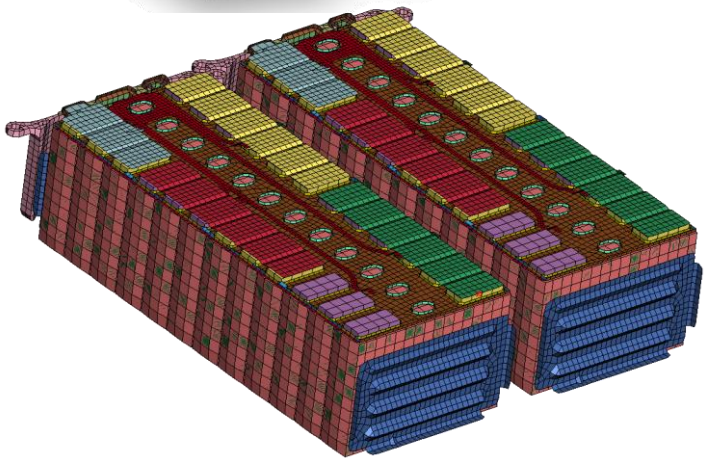



# BATTERYMODEL FOR FULL VEHICLE SIMULATION
## EM SIMULATION OF BATTERY PACK

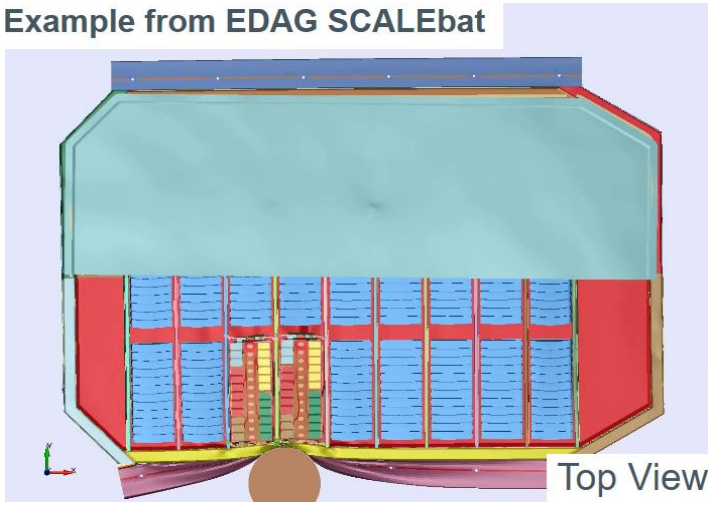
- Design of a battery with 100 electrically simulated prismatic cells
- Use of the Randles Batmac Model
- Model size ~1,500,000 elements for the electrical cells
- Parameters determined by electrochemical impedance spectroscopy
- Mechanical behavior from an adapted pouch cell model
- Computing time ~ 10h for 80ms on 96 CPU strongly dependent on EM time step

➢ Successful detection of the short circuit

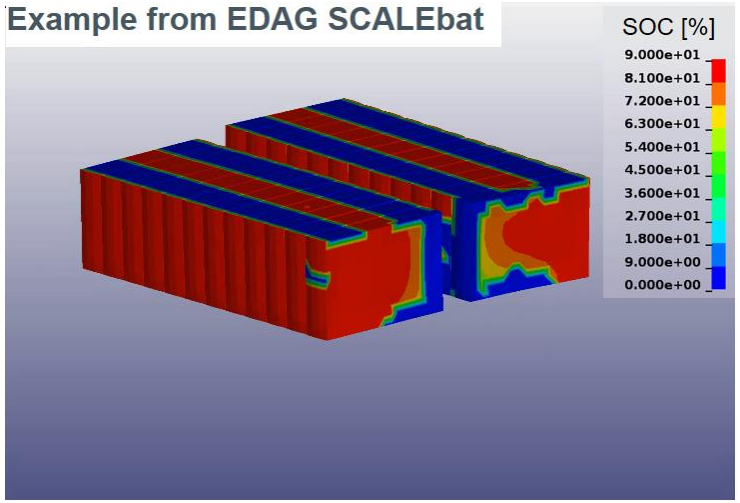
**EDAG SCALEbat**



**Example from EDAG SCALEbat**




**Example from EDAG SCALEbat**



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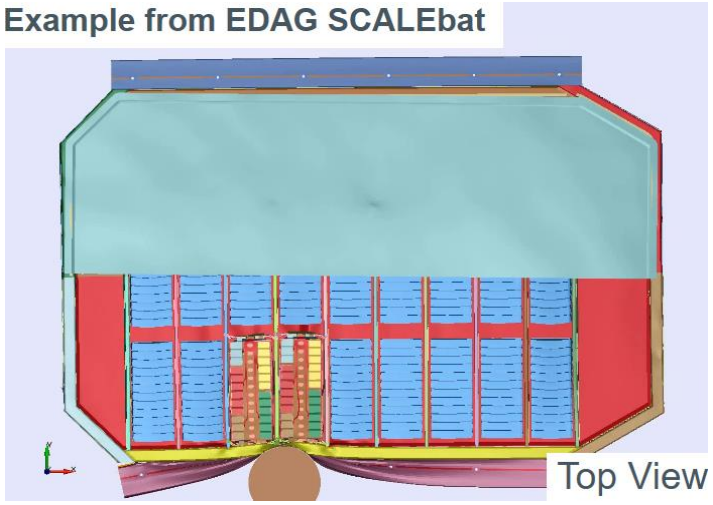


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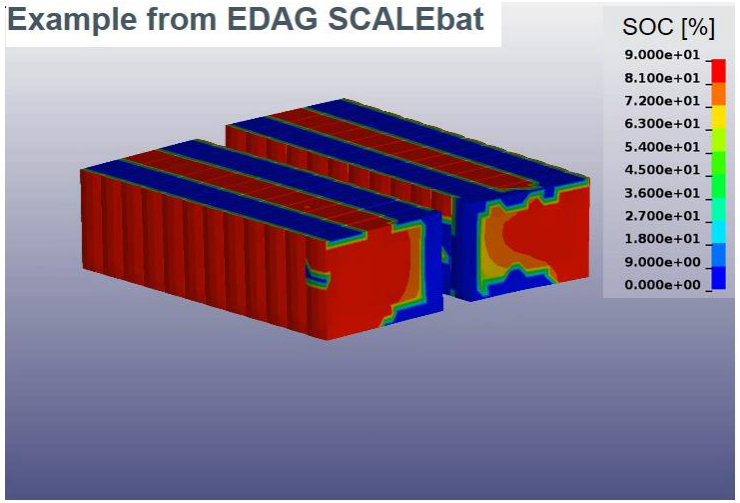
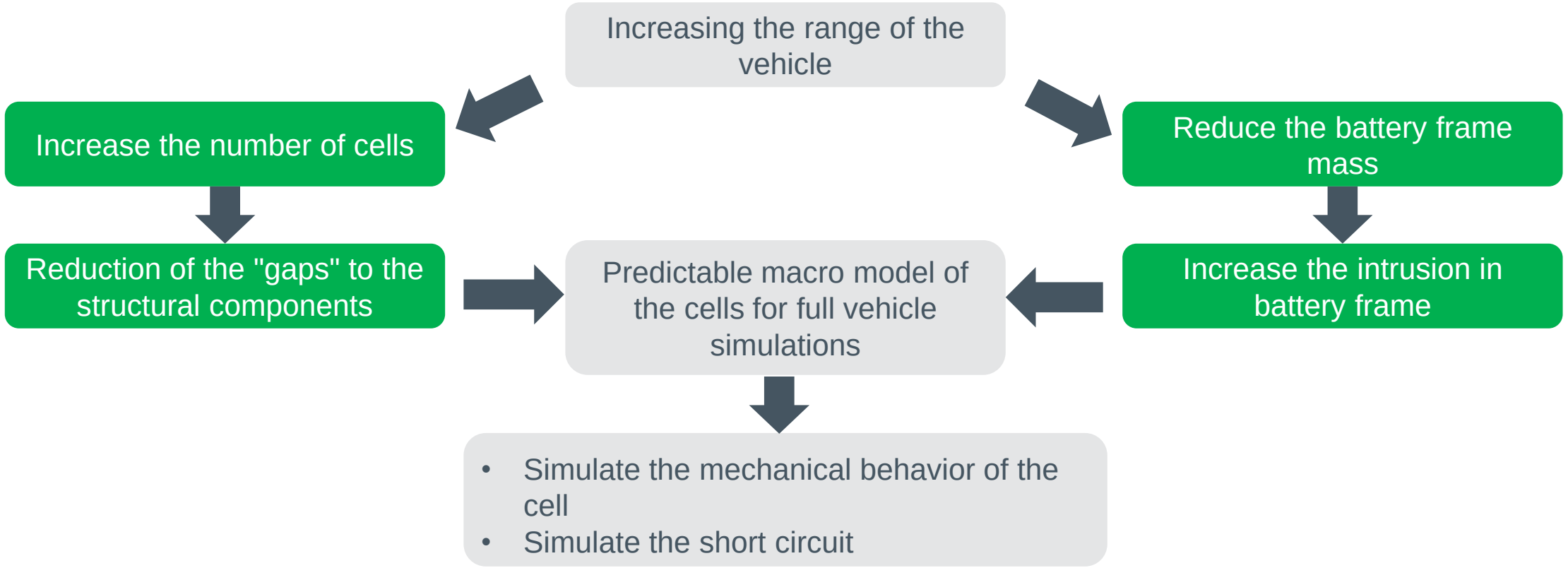



**Benefits in the Project for a B-Segment car:**

➢ Increase Vehicle Range:
  ➢ + 50km WLTP (13%)

➢ Reduce Frame Weight:
  ➢ - 20kg (-33%) on the crash parts of battery frame

# BATTERYMODEL FOR FULL VEHICLE SIMULATION
## BENEFITS BY USING A BATTERY SIMULATION



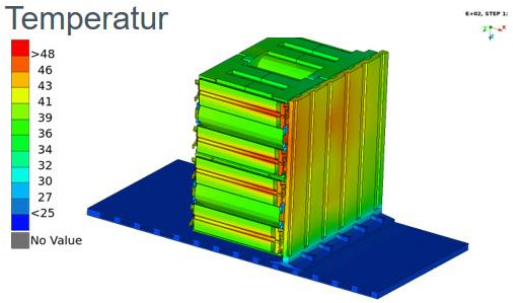
# BATTERYMODEL FOR FULL VEHICLE SIMULATION
## SUMMARY

- EDAG has a battery macro model for full vehicle simulation

- We are able to support the development of battery electrical vehicles by:
  - Simulate the mechanical behavior of the cell
  - Simulate the short circuit
  - Optimization of the battery frame
  - Increase the amount of cell

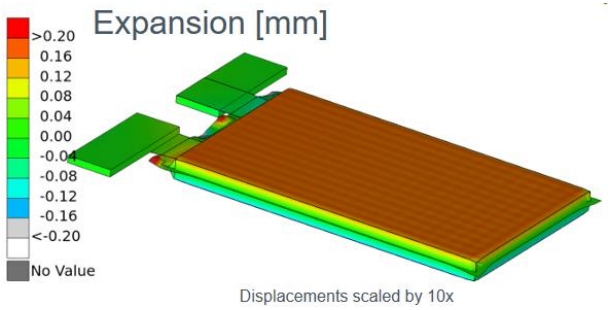
  for all common types of cells

  ➢ Increase the vehicle range




➢ The battery design is done in close cooperation with our electrical engineers

➢ Thermal simulations and battery swelling is also a part of our development



# CONTACT


**Stanislaw Rybak**

Project Leader Sindelfingen

Mobil: +49 (171) 3111 889
Email: stanislaw.rybak@edag.com



**Mathias Gerster**

Head of Department Sindelfingen

Tel.: +49 (7031) 861-735
Mobil: +49 (151) 54 35 92 08
Email: mathias.gerster@edag.com